SPECIFICATION

THREE-DIMENSIONAL IMAGE PROCESSING SYSTEM WITH HIGHLY RESPONSIVE MOVING OBJECT DIRECTION AND SPEED CONTROL

FIELD OF THE INVENTION

5   This invention relates to three-dimensional image processing systems. More particularly, this invention is concerned with a three-dimensional image processing system for video game machines or the like, which is adapted to display an object in a realistic manner in a

10   three-dimensional space on a display such that the object is moved in accordance with the direction and amount of inclination of an operating member, such as an analog joystick, of an operating device, e.g., a video game controller.

BACKGROUND OF THE INVENTION

15   The conventional video game machine has a cross-shaped key which is provided on a controller so that the object displayed on the display is moved by a player's operation of the cross key. Such a cross key is a so-called digital joystick, by which only the direction of movement is designated for the object. With such a cross key, the

20   speed of movement is impossible to designate.

There also is a prior art method where moving speed of the object is varied depending upon the length of the time period over which a cross key is depressed. In such a method, acceleration or deceleration is determined for the object at a constant acceleration

5 rate or a constant deceleration rate by each constant depression time period. Although, in this method, the moving direction and the moving speed of the object can be controlled even by using a digital joystick, there are disadvantages using this approach. That is, the moving speed for the object is merely varied at a constant rate of

10 acceleration or deceleration as determined by software calculations, so that is impossible to arbitrarily control the speed of movement. Furthermore, the speed is determined by the period of key depression time, which requires that the cross key has to be kept depressed for a certain period or longer, resulting in poor responsiveness.

15 Under such circumstances, the present applicant has proposed by Japanese Provisional Utility Model Publication No. H2-41342, laid open to public on March 22, 1990, a controller which has three contacts arranged in one direction on a cross key thereof so that the moving speed, besides the moving direction, is varied for the object

20 by utilization of changing turning-on of contacts depending upon depression amount of the cross key.

In this prior art, however, the direction of movement is limited to four directions of upper, lower, left and right (and intermediate

directions thereof), and the speed of movement is varied only between three stages of speed. That is, in this prior art there still exists limitations on the moving direction and the moving speed.

Although there are already known game machines employing an analog joystick for a control lever of an aircraft, such an analog joystick of the game machines are typically utilized for controlling, for example, the inclination of the aircraft, and wherein control is impossible for the moving direction or the moving speed.

SUMMARY OF THE INVENTION

It is therefore the primary object of the present invention to provide an image processing system which is high in responsiveness and is capable of controlling the moving direction and the moving speed of a player controlled object.

The present invention is directed to a three-dimensional image processing system, including an image processing apparatus connected to a display to generate image data for displaying an object existing in a three-dimensional space on the display according to a stored program, and an operating device including an operating member having a base end rotatably supported and a free end

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operable by an operator, so that the image data is varied in accordance with movement of the operating member. The operating device includes inclination amount data output circuitry which detects an inclination amount of the operating member to output

5   inclination amount data. The exemplary image processing apparatus includes direction determining hardware and software which determines a moving direction of the object in the three-dimensional space based on the inclination amount data; moving amount determining hardware and software which determines a moving

10   amount of the objection within one display frame; position determining hardware and software which determines object position in the three-dimensional space in accordance with the moving direction and the moving amount; and an image data output circuitry which outputs image data for displaying the object on the display at a

15   position controlled by the position determining hardware and software.

The operating device is, for example, an analog joystick, which includes a base end supported rotatably with a given angle range and a free end for being operated by an operator so that the operating

20   member is inclined to arbitrary directions in accordance with operator operation. For example, an inclination amount data output circuitry such as an X counter and a Y counter detects the amount of inclination of the operating member to output inclination amount data.

The image processing apparatus includes a program storing memory, wherein the program storing memory is preferably an external storage device detachably attached to the image processing apparatus main body. Direction determining circuitry and moving

5   amount determining circuitry comprised, for example, of a CPU under control of the stored program respectively determine moving direction of the object in the three-dimensional space and moving amount of the object to be moved in one display frame, based on the inclination amount data from the operating device.

10   Specifically, count values of an X counter and the Y counter are converted by normalizing into a UV coordinate frame. The CPU determines the inclination amount (L) and the inclination direction $(\tan^{-1})$ by the UV coordinate value (u, v). The direction determining circuitry is, for example, the CPU, which determines under program

15   control the moving direction of the object based on the inclination direction $(\tan^{-1})$ thereof and the point of view (camera angle) at which the object is considered to be "photographed" in the three-dimensional space. The moving amount determining circuitry is, for example, the CPU, which determines under the program control the

20   moving amount of the object within one display frame, i.e., the moving speed, based on the inclination amount (L) and the maximum speed (max-speed).

Therefore the position determining circuitry determines the position of the object in three-dimensional space in dependence upon the moving direction and the moving amount. Consequently, the image data output circuitry outputs image data for display of the

5 object at the position thus determined.

In accordance with the present invention, the operation of one operating device such as an analog joystick provides control of the moving direction and the moving amount (moving speed) of the object.

10 The above and other objects, features, aspects, and advantage of the present invention will become more apparent from the ensuing detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

15 Figure 1 is a schematic illustrative view showing one embodiment of the present invention;

Figure 2 is a block diagram showing an illustrative image processing apparatus in the Figure 1 embodiment;

Figure 3 is a block diagram showing in more detail an illustrative bus control circuit in the Figure 2 embodiment;

Figure 4 is an illustrative view showing a memory map of a RAM in the Figure 2 embodiment;

5   Figure 5 is a block diagram showing a controller control circuit in the Figure 2 embodiment;

Figure 6 is an illustrative view showing a memory map of a RAM in Figure 5;

Figure 7 is a perspective view of a controller in the Figure 2

10   embodiment as viewed from the top;

Figure 8 is a perspective view of the controller in the Figure 2 embodiment as viewed from the bottom;

Figure 9 is a block diagram showing in detail the controller and an extension device;

15   Figure 10 is an illustrative view showing data of an analog joystick of the controller and respective buttons;

Figure 11 is a flowchart showing the operation of a CPU in the Figure 2 embodiment;

Figure 12 is a flowchart showing the operation of the bus control circuit in the Figure 2 embodiment, i.e., an RCP (Reality Co-Processor) in Figure 3;

Figure 13 is a flowchart showing the operation of the controller control circuit in the Figure 2 embodiment;

Figure 14 is a flowchart showing a subroutine for varying the position of the object in the Figure 2 embodiment;

Figure 15 is an illustrative view showing the relation between the inclinable range of the analogy joystick and the circular correction therefore;

Figure 16 is an illustrative view showing the moving direction of the object.

EMBODIMENTS

Referring to Figure 1, there is illustrated an external view showing an exemplary three-dimensional image processing system according to one embodiment of the present invention. The image processing system is, for example, a video game system, which includes an image processing apparatus main body 10, a ROM cartridge 20 (as one example of an external memory device), a

television type monitor 30 (as one example of a display means) connected to the image processing apparatus main console 10, a schematically represented illustrative controller 40, and a RAM cartridge 50 (as one example of an extension device detachably

5   attached to the controller 40). The external memory device stores image data and program data for image processing for games, an audio data for music, sound effects, etc. A CD-ROM or a magnetic disc may alternatively be employed in place of the ROM cartridge. Where the image processing system of this exemplary embodiment is

10   applied to a personal computer, an input device such as a keyboard or a mouse may be used as the operating mechanism.

Figure 2 is a block diagram of an exemplary image processing system. The image processing apparatus 10 incorporates therein a central processor unit (hereinafter "CPU") 11 and a bus control

15   circuit 12. The bus control circuit 12 is connected to a cartridge connector 13 for detachably attaching a ROM cartridge 20, and a RAM 14. The bus control circuit 12 is connected to an audio signal generating circuit 15 for outputting an audio signal processed by the CPU 11 and a video signal generating circuit 16 for outputting a

20   video signal, and further to a controller control circuit 17 for serially transferring operating data from one or a plurality of controller(s) 40 and/or data from RAM cartridge(s) 50. The controller control circuit 17 is connected to controller connectors (hereinafter abbreviated as "connectors") 181-184 which are provided at a front console face of

the image processing apparatus 10. A connection jack 41 is

detachably connected to connector 181-184 and to the controllers 40

through a cable 42. Thus, the connection of the controller 40 to the

connector 181-184 places the controller 40 into electric connection

5   with the image processing apparatus 10, enabling transmission and

reception of data therebetween.

More specifically, the bus control circuit 12 receives a

command output as a parallel signal from the CPU 11 via a bus and

converts it to a serial signal for outputting a serial signal command to

10   the controller control circuit 17, and converts serial signal data input

from the controller control circuit 17 into a parallel signal for output

to a bus. The data output through the bus is processed by the CPU

11, and may be stored in RAM 14. RAM 14 is a memory for

temporarily storing the data to be processed by the CPU 11, wherein

15   read-out and writing of data is possible through the bus control

circuit 12.

The bus control circuit 12, included in the image processing

apparatus 10 in Fig. 2, for example, includes a coprocessor RCP

(Reality Co-Processor) which may be a RISC processor. As shown in

20   the Fig. 3 exemplary embodiment, the coprocessor RCP includes an

I/O control 121, a signal processor 122 and a display or drawing

processor 123. The I/O control 121 controls not only the transfer of

data between the CPU 11 and the RAM 14, but also the flow of data

between the signal processor 122 or the drawing processor 123 and the RAM 14 or the CPU 11. That is, data from the CPU 11 is delivered to the RAM 14 via the I/O control 121, and further data from the RAM 14 is supplied to the signal processor 122 and the

5   drawing processor 123 for processing therein. The signal processor 122 and the drawing processor 123 respectively process music signal data and image signal data and store such data in RAM 14. The I/O control 121 then reads the music signal data and the image signal data out of the RAM 14 according to instructions executed by the CPU 11

10   to supply respective signals to a music signal generating circuit (D/A converter) 15 and an image signal generating circuit (D/A converter) 16. The music signal is supplied via a connector 195 to a speaker 31 included in a TV monitor 30. The image signal is supplied via a connector 196 to a display 32 included in the TV monitor 30.

15   A disc driver 21 may be connected to the image processing apparatus 10 as shown in Fig. 3, in place of or together with the external ROM 20 wherein the disc driver can read out of or write to an optical disc or a magnetic disc. In this case, the disc driver 21 is connected to the RCP 12, i.e., the I/O control 121, through a

20   connector 197.

Fig. 4 is an illustrative diagram showing memory areas assigned to CPU 11 memory address space. The RAM address space is accessible by the CPU via the bus control circuit, i.e., the RCP 12

and includes an image data region 201 for storing image data

required to cause the image processing apparatus 10 to generate

image signals for the game, and a program data region 202 for storing

program data required for controlling predetermined CPU 11

5   operations. In the program data region 202, there are fixedly stored

an image display program for performing image display processing

based on image data 201, a time-measuring program for performing

processing relating to the measurement of time, and a determination

program for determining that the cartridge 20 and an extension device

10   50, hereinafter referred to, have a predetermined relationship. The

RAM 14 includes further a region 141 for temporarily storing data

representative of an operating state from a control panel or controller

and a speed data region 142 for storing data indicative of the speed of

object movement (the amount of movement over which the object

15   moves in one display frame).

The controller control circuit 17 is provided for transmission

and reception of data in serial between the bus control circuit 12, i.e.,

the RCP, and the connector 181-184, and includes as shown in Fig. 5

a data transfer control circuit 171, a signal transmitting circuit 172, a

20   signal receiving circuit 173 and a RAM 174 for temporarily storing

transmission and reception data. The data transfer control circuit 171

includes a parallel-serial conversion circuit and a serial-parallel

conversion circuit for data format conversion during data transfer,

and also controls write-in and read-out of the RAM 174. The serial-

parallel conversion circuit converts serial data supplied from the bus
control circuit 12 into parallel data to provide it to the RAM 174 or
the signal transmitting circuit 172. The parallel-serial conversion
circuit converts parallel data supplied from the RAM 174 or the

5   signal receiving circuit 173 into serial data to provide to the bus
control circuit 12. The signal transmission circuit 172 converts data
for signal read-in control of the controller 40 supplied from the data
transfer control circuit 171 and converts write-in data (parallel data)
to the RAM cartridge 50 into serial data, which data is transmitted

10   through a corresponding channel CH1-CH4 to each of the plurality of
controllers 40. The signal receiving circuit 173 receives data in serial
form representative of an operating state of each of the controllers 40,
input through a corresponding channel CH1-CH4 and read-out data
from the RAM cartridge 50, to convert such data into parallel data to

15   provide to the data transfer control circuit 171.

The RAM 174 of the controller control circuit 17 includes
memory regions or memory areas 174a-174h as shown in a memory
map of Figure 6. Specifically, the area 174a stores a command for
channel 1, while the area 174b stores transmission data and reception

20   data for channel 1. The area 174c stores a command for channel 2,
while the area 174d stores transmission data and reception data for
channel 2. The area 174e stores a command for channel 3, while the
area 174f stores transmission data and reception data for channel 3.

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The area 174g stores a command for channel 4, while the area 174h stores transmission data and reception data for channel 4.

Accordingly, the data transfer control circuit 171 operates to control writing to the RAM 174 data transferred from the bus control circuit 12 or data indicating the operating state of the controller 40 received by the signal receiving circuit 173. The data transfer control circuit 171 operates to control reading out of data from the RAM cartridge 50, and reading data out of the RAM 174 based on a command from the bus control circuit 12 to transfer such data to the bus control circuit 12.

Figure 7 and Figure 8 are external perspective views of front and back surfaces of a controller 40. The controller 40 is shaped such that it can be grasped by both hands or one hand, and has a housing having an exterior formed with a plurality of projecting buttons or control keys which, when depressed, generate an electric signal and a vertically-standing control member portion. Specifically, the controller 40 includes an upper housing and a lower housing. The housing of the controller 40 has an operating area formed on an upper surface in a planar shape extending sideways. The operating area of the controller 40 includes a cross-shaped digital direction switch (hereinafter referred to as "cross switch") 403 on a left side, a plurality of button switches (hereinafter referred to as "switches") 404A-404F on a right side, a start switch 405 generally at

a laterally central portion, and a joystick 45 providing analog input at a centrally lower portion. The cross switch 403 is a direction switch for designating the direction of movement of a player controlled heroic character or a cursor, which has upper, lower, left and right

5   depression points used for designating movement in four directions. The switches 404A-404F, may have different functions as defined by game software and may be used, for example, to launch a missile in a shooting game, or designate various actions such as jumping, kicking, or controlling an action game in many different ways. The

10   joystick 45 may be used in place of the cross switch 403 to designate the direction of movement of an object. It can designate direction over the entire angular range over 360 degrees, being utilized as an analog direction designating switch.

The housing of the controller 40 has three grips 402L, 402C

15   and 402R formed in a manner projecting downward from three locations of the operating area. The grips 402L, 402C and 402R are in such rod-shapes that, when held by the hand, they are contoured by the palm, the middle finger, the finger between the little and the middle finger and the little finger. Each grip is formed by a relatively

20   thin base portion, a thicker intermediate portion which thins toward an open end (downward in Figure 7). The bottom housing the controller 40 has an insertion aperture 408 formed at a centrally upper portion which projects from the underside for detachably attached, for example, a RAM cartridge 50 as an extension device.

The housing has a button switch 406L and a button 406R provided on left and right upper side faces thereof at locations corresponding to the positions to which the left and right index fingers of a player extend. On a back surface at the base portion of the central grip 402C, a switch 407 is provided as a switch having a function similar to the switch 406L when the joystick 45 is used in place of the cross switch 403 (or whose function may be varied in accordance with the game program).

The lower half of the housing on a back surface side extends toward a bottom surface to have the aperture 408 formed at a tip end thereof. At a deep end of the aperture 408, a connector (not shown) is provided to which an extension cartridge 50 is to be connected. In the aperture 408 a lever 409 is also formed for ejecting the cartridge 50 inserted in the aperture 408. On a side opposite to the lever 409 in the aperture 408 for insertion of an extension cartridge 50, a cut-out 410 is formed, which cut-out 410 provides a space for pulling out the extension cartridge 50 upon taking out the extension cartridge 50 by using the lever 409.

Figure 9 is a detailed circuit diagram of a controller 40 and a RAM cartridge 50 shown as one example of an extension or expansion device. The controller 40 incorporates within the housing electronic circuits such as operation signal processing circuit 44

6, etc. in order to detect operating states of the switches 403-407 or the joystick 45 or the like and transfer detected data to the controller control circuit 17. The operation signal processing circuit 44 includes a signal receiving circuit 441, a control circuit 442, a

5   switch signal detecting circuit 443, a counter circuit 444, a signal transmitting circuit 445, a joyport control circuit 446, a reset circuit 447 and a NOR gate 448.

The signal receiving circuit 441 converts a serial signal, such as a control signal transmitted from the controller control circuit 17,

10 or write-in data to the RAM cartridge 50, etc. into a parallel signal to supply it to the control circuit 442. The control circuit 442 generates a reset signal to cause resetting (0) of measured values of an X-axis counter 444X and a Y-axis counter 444Y included in the counter 444, when the control signal transmitted from the controller control circuit

15 17 is a reset signal for an X, Y coordinate of the joystick 45. The joystick 45 includes photo-interrupters for the X-axis and the Y-axis to generate a number of pulses proportional to the amount of inclination of a lever in directions of the X-axis and Y-axis, providing respective pulse signals to the counters 444X and 444Y.

20 The counter 444X, when the joystick 45 is inclined in the X-axis direction, measures the number of pulses generated in proportion to the amount of inclination. The counter 444Y measures the number of pulses generated in proportion to the amount of inclination, when the joystick 45 is inclined in the Y-axis direction. Accordingly, the

resultant vector, determined by the measured values in X-axis and Y-axis of the counter 444X and the 444Y, determines the moving direction and the moving speed for the displayed player controlled object or the cursor.

5   The counter 444X and the counter 444Y are also reset of their measured values by a reset signal supplied from the reset signal generating circuit 447 upon turning on the power supply, or a reset signal supplied from the switch signal detecting circuit 443 when the player simultaneously depresses two switches.

10   The switch signal detecting circuit 443 responds to an output command signal representing a switch state supplied at a constant period (e.g., at a 1/30-second interval in a frame period of a television), and reads a signal that is varied by the state of depression of the cross switch 403 and the switches 404A-404F, 405, 406L, 15 406R and 407 to supply it to the control circuit 442.

The control circuit 442 responds to a read-out command signal of operating state data from the controller control circuit 17, and supplies the operating state data of the switches 403-407 and the measured values of the counters 444X, 444Y to the signal 20 transmitting circuit 445 in a predetermined data-format order. The signal transmitting circuit 445 converts these parallel signals output from the control circuit 442 into serial data to transfer them to the

controller control circuit 17 via a conversion circuit 43 and a signal line 42.

To the control circuit 442 are connected an address bus, a data bus, and a port control circuit 446 through a port connector 40. The port control circuit 446 performs input-output control (or signal transmission or reception control) on data according to commands from the CPU 11, when the RAM cartridge 50, which is one example of an extension device, is connected to a port connector 46. The RAM cartridge 50 includes a RAM 51 which is connected to the address bus and the data bus, and which includes a battery 52 for supplying power source to the RAM 51. The RAM 51 may, for example, be a RAM that has a capacity lower than a half of a maximum memory capacity accessible by using an address bus, and may, for example, be a 256 k-bit RAM. The RAM 51 stores backup data associated with a game, so that, if the RAM cartridge 50 is removed from the port connector 46, the stored data is maintained by receiving power supply from the battery 52.

Figure 10 is a graphical illustration of a data format by which the image processing apparatus reads out data representative of an operating state of switches 403-407 and joystick 45 from the controller 40. The data generated by the controller 40 is configured as 4-byte data. The first-byte data B, A, G, START, upper, lower, left and right, i.e., represents the state of switches 404B, 404A, 407, 405

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and cross switch 403. For example, when the button B, i.e., the switch 404B, is depressed, the highest order bit of the first byte becomes "1". Similarly, the second-byte represents JSRST, 0 (not employed in the exemplary embodiment), L, R, E, D, C and F, i.e.,

5   the state of the switches 409, 406L, 406R, 404E, 404D, 404C and 404F. The third byte represents by binary digit the X coordinate value (measured value by the X counter 444X) which value depends upon the inclination angle of the joystick 45 in the X direction. The fourth byte represents by binary digit the Y coordinate value

10   (measured value by the Y counter 444Y) which value depends upon the inclination angle of the joystick 45 in the Y direction. Because the X and Y coordinate values are expressed by 8 bits of binary digit, the conversion into decimal digit makes it possible to represent the inclination of the joystick 45 by a numeral of from 0-255. If the

15   highest order bit is expressed by a signal denoting a negative value, the inclination angle of the joystick 45 can be expressed by a numeral between -128 and 127.

An explanation of the transmission and reception of data between the image processing apparatus 10 and the controller 40, as

20   well as the operation of object movement control according to the data from the controller 40 is set forth below.

Referring first to a Figure 11 flowchart for the CPU 11 of the image processing apparatus 10, an explanation is made concerning

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image processing. At a step S11, CPU 11 is initialized based on an initial value stored in the program data area 202 in Figure 4. At a step S11, the CPU 11 set for example to the initial value of the moving speed of the object in the program data region 142 (Figure 4)

5   of the RAM 14. Then, at a step S12, CPU 11 outputs a control pad data request command stored in the program data area 202 to the RCP (the bus control circuit 12). Accordingly, at the step S12, the CPU 11 receives commands as shown in Fig. 10 at that time to store them to command accommodating storage sites 174a-174d for respective

10   channels. At this time, the count values of the X counter 444X and the y counter 444Y are provided to the CPU 11 as XY coordinate data.

. Then at a step S12a the CPU 11 execute processes to alter the position of the object in accordance with joystick data from the

15   controller 40 which has been stored in the command accommodating sites 174a-174d for the channels (Fig. 6). Note that the step S12a is explained in detail below with reference to Fig. 14.

At a step S13, the CPU 11 carries out predetermined desired image processing based on the program stored in the program data

20   area 202 and the image data 201. While the CPU 11 is executing the step S13, the RCP (bus control circuit 12) is executing steps S21-S24 shown in Figure 12. Then, at a step S14, the CPU 11 outputs image data based on the control pad data stored in the control pad data area

141 in Figure 4. After completing step S14, the CPU 11 repeats to execute steps S12-S14.

The operation of the RCP (the bus control circuit 12) is explained in conjunction with Figure 12. At a step S21, the bus control circuit 12 determines whether or not the CPU 11 has output a controller data request command (a request command for data on switches of the controller 40 or data relating to the expansion device 50). If a controller data request command has not been output, the RCP waits until one is output. If a controller data request command has been output, the process proceeds to a step S22. At step S22, the bus control circuit 12 outputs a command for reading in controller 40 data to the controller control circuit 17. Then, at a step S23, the bus control circuit 12 determines whether or not the controller control circuit 17 has received data from the controller 40 to store it in the RAM 174. If the controller control circuit 17 has not received data from the controller 40 to store in the RAM 174, the bus control circuit 12 waits at step S23. The controller control circuit 17 has received data from the controller 40 to store it in the RAM 174, the process proceeds to a step S24. At the step S24, the bus control circuit 12 transfers the data of the controller 40 stored in the RAM 174 to the RAM 14. The bus control circuit 12, when completing the data transfer to the RAM 14, returns the process back to the step S21 to repeat execution of the steps S21 - the step S24.

The Figure 11 and Figure 12 flowcharts show the example wherein, after the bus control circuit 12 has transferred data from the RAM 174 to the RAM 14, the CPU 11 processes the data stored in the RAM 14. However, the CPU 11 may directly process the data in

5   the RAM 174 through the bus control circuit 12.

Figure 13 is a flowchart for explaining the operation of the controller control circuit 17. At a step S31, it is determined whether there is a write wait from the bus control circuit 12. If there is not a write wait, the data transfer control circuit 171 waits until there is a

10   write wait from the bus control circuit 12. If there is a write wait, at a next step S32 the data transfer control circuit 171 causes the RAM 174 to store commands for the first to the fourth channels and/or data (hereinafter abbreviated as "command/data"). At a step S33, the command/data for the first channel is transmitted to the controller 40

15   connected to the connector 181. The control circuit 442 performs a predetermined operation based on the command/data to output data to be transmitted to the image processing apparatus 10. The content of the data is described below in explaining the operation of the control circuit 442. At a step S34, the data transfer control circuit 171

20   receives data output from the control circuit 442, to cause the RAM to store the data.

At a step S35, the command/data for the second channel is transmitted to the controller 40, in a manner similar to the operation

for the first channel at the steps S33. The control circuit 442

performs a predetermined operation based on this command/data to

output the data to be transmitted to the image processing apparatus

10. At a step S36 data transfer and write-in processes are carried out

5   for the second channel. Meanwhile, at a step S37, the command/data

for the third channel is transmitted to the controller 40. The control

circuit 442 performs a predetermined operation based on this

command/data to output the data to be transmitted to the image

processing apparatus 10. At a step S38 data transfer and write-in

10   processes are carried out for the third channel. Furthermore, at a step

S39, the command/data for the fourth channel is transmitted to the

controller 40. The control circuit 442 of the controller 40 performs a

predetermined operation based on this command/data to output the

data to be transmitted to the image processing apparatus 10. At a step

15   S40 data transfer and write-in processes are carried out for the fourth

channel. At as subsequent step S41, the data transfer circuit 171

transfer in batch the data which it received at the steps S34, S36, S38

and S40 to the bus control circuit 12.

In the above-identified manner, the data for the first channel to

20   the fourth channel, that is, the commands for the controllers 40

connected to the connectors 181-184 and the operating state data to

be read out of the controllers 40, are transferred by time-divisional

processing between the data transfer control circuit 171 and the

control circuit 442 respectively within the controllers 40.

With reference to Figure 14, object position modifying step
S12a in Fig. 11 is explained in detail. At a first step S301 in Figure
14, the CPU 11 corrects the joystick data, i.e., the X coordinate data
and the Y coordinate data, from the controller 40. The joystick 45

5   (Figure 7) has a structure that can be inclined within an octagonal
range 451 in a plane as shown in Fig. 15. Accordingly at the step
S301, the data within the octagonal range of inclination is converted
or corrected into data within a circular range 452. There is no
necessity of executing the correcting step. That is, the subsequent

10   steps may be executed with the octagonal inclination range data.

At the step S301, the XY coordinate data for the joystick 45 is
converted into coordinate data (u, v) in an UV plane as shown in Fig.
15. On this occasion, the maximum amount of inclination of the
joystick 45 is normalized to "1". That is, the joystick 45 in the UV

15   plane in Figure 15 is allowed to incline within respective ranges of -
1.0 # u # 1.0 and -1.0 # v. # 1.0. This is because, since a square curve
is utilized to calculate the moving speed S of the object as stated
later, a low speed range thereof is to be extended. In this manner, it
becomes possible to move the object at a considerably slow speed.

20   At subsequent steps S302, S303 and S304, the CPU 11
calculates or detects the amount of inclination L of the joystick 45,
the moving speed S of the object and the moving direction ∀ thereof

according to following Equations (1), (2) and (3), based on the
corrected joystick data (u, v),

$$L = \text{the square root of "} u^2 + v^2 \text{"} \qquad \ldots (1)$$

$$S = L^2 \text{ X max - speed} \qquad \ldots (2)$$

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$$\forall = \tan^{-1}(u/-v) + \text{camera-angle} \qquad \ldots (3)$$

where, L: the inclination amount of the joystick, u, v: is the
inclination amount in each axis (coordinate positions), S: is the
moving speed of the object, where the max-speed: self-running
maximum speed (e.g., 32 cm/frame), $\forall$: the direction of object
10 movement. Equation (3) means that in a three-dimensional space the
direction $\forall$ of object movement is determined by the relative
relations between the direction of joystick 45 inclination and the
point of view or angle of a camera (camera-angle) at which the object
is "photographed" in three-dimensional space.

15 After calculating respectively at the steps S302, S303 and S304
the inclination amount L of the joystick, the moving speed S of the
object and the moving direction $\forall$ thereof in accordance with
Equations (1), (2) and (3), the CPU 11 at a step S305 compares the
actual moving speed S1 of the object in the previous frame stored at
20 the speed data region 142 of the RAM 14 with the speed S calculated

at the step S303, determining whether they are equal to or not. If they are not coincident (S1 is not = to S), the CPU 11 determines whether S1 > S at a next step S306.

If the determination is "No" at step S306, the process of acceleration is executed at a step S307, while if "Yes" is determined, the process of deceleration is executed at a step S308. In the acceleration process at the step S307, a predetermined acceleration A is added to the actual moving speed S1 in the previous frame according to Equation (4). Note that the acceleration A is provided as one example by following Equation (5):

$$S = S1 + A \qquad \qquad \dots \ (4)$$

$$A = 1.1 - S1/43.0 \qquad \qquad \dots \ (5)$$

Also, in the deceleration process at the step S308, a predetermined deceleration B is subtracted from the actual moving speed S1 in the previous frame according to Equation (6). Note that the deceleration B is provided as one example by following Equation (7):

$$S = S1 - B \qquad \qquad \dots \ (6)$$

$$B = 2.0 \qquad \qquad \dots \ (7)$$

The reason for determining in Equation (5) the acceleration A based on the speed S1 in the previous frame is to avoid abrupt changes of speed. Although in Equation (7) the deceleration B was set as a constant, it may alternatively be set as a function of moving speed S1 in the previous frame in a manner similar to the acceleration A. Furthermore, the acceleration A may be a constant value.

If "Yes" is determined at step S305, the process proceeds to a step S309 as is the case when executing steps S307 or S308. At step S309, either of the moving speed S determined at the step S307 or the moving speed determined at step S308 is written in the speed data region 142 of the RAM 14, thereby updating the speed data.

At a next step S310, the position x and z of the object is calculated according to following Equations (8) and (9), based on the moving speed thus determined. That is, the position of the object is determined by the vector amount S and the vector angle $\forall$.

$$X = x + S \times \sin \forall \qquad \ldots (8)$$

$$z = z + S \times \cos \forall \qquad \ldots (9)$$

At a step S311, the CPU 11 outputs the position data determined by Equations (8) and (9) to the bus control circuit, or the RCP, 12. In response, the RCP 12 executes signal processing and

image processing in dependence upon the object position data given thereto, and outputs image data through the I/O control 12 to the D/A converter 16.

In this manner, the moving direction and the moving amount 5 (moving speed) of the object are determined in the above example based on the inclination amount data for the controller 40 joystick, thereby varying the position of the object in the three-dimensional space. In other words, the object is displayed at a position thus varied in the next frame on the display 32 (monitor 30).

10 Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.

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